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The role of daylight in preserving identities in heritage context

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Abstract

The narrow alleys and the small neighbourhood squares are the most recognisable urban configuration forms that highlight the fabrics of Old Cairo. Parts of Old Cairo are currently going through major conservation projects. The extent of the success of some of these projects in preserving the identity of the Cairene context is currently under scrutiny and has created a debate among local residents, professionals, and politicians. Preliminary investigation has been conducted to assess the rehabilitation strategy of the selected case of el-Darb el-Asfar in relation to its context. Daylight is an essential contextual ingredient that characterises particular places from its counterparts. The rehabilitation project, using new finishing materials, has led to changes in daylight levels and reflections in the space and hence modify the visual perception and the identity of the place itself. This paper aims to assess the impact of the proposed intervention on the visual perception and the identity of the selected built heritage. Daylight variables in open spaces, a combination of sunlight, skylight and the reflected light from the facades and the ground, are identified. Using TOWNSCOPE, daylight's components are calculated pre and after the implementation of the project. The performance of reflected component is traced by simulating the impact of the original and recently used materials. The paper concludes by suggesting a set of measures to achieve an appropriate daylight performance to achieve a sustainable development in the area and maintain the identity of the old city.

Keywords: Daylight; Place identity; Solar simulation; Sustainable-place making; Urban morphology

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Contents

1. Introduction: rehabilitation projects of medieval Cairo

Several projects are currently taking place in the medieval quarters of Cairo. There is a significant debate on whether such intervention has negatively affected the identity of the area. This paper reviews two of these projects, the rehabilitation of Aslam Square and the refurbishment of the alleyway in el-Darb el-Asfar. The significance of Aslam Square lies in its location, urban form and association with historical landmarks. Its proximity to Bab al-Mahruq, one of the principle historic gates existed along the eastern side of the Ayyubid city wall, raises an interest in the area and inspires an idea of re-creating the old threshold (Fig. 1). In addition to its specific merit, being located a few meters away from the eastern edge of historic Cairo; the square also forms a vital link to thoroughfares leading west, north and south. Its ability to accommodate a variety of daily activities and one of Cairo's annual major local festivals accentuates its peculiarity in the cultural context [1]. Aslam Square represents, therefore, an important ingredient of the regeneration of the area.

The configuration of Aslam Square is marked by the composition of Aslam mosque dating back to the *Mamluk* period (1344–35). A series of local commercial shops facing the southern stone facades of the mosque (Fig. 2) occupies the southern side of the square. Multi use commercial and residential blocks line the square on the east and the west sides. The rectangular-shape of the square is around 15.10 m × 28.50 m with a range of width to height ratios. Some poorly maintained overhangs and shading devices are found covering parts of the southern portion of the ground in front of the shops adding to the shading devices on the eastern and the western facades. Apart from the tilted platform along the façade of the mosque, the ground cover in the square comprises mostly asphalt paving (currently in poor condition). The square currently is poorly organised where the portion adjacent to the above northern platform is occupied by some semi-fixed elements and the rest of the open space is used for informal parking.

In order to encourage informal contact and community life, a number of objectives have been addressed in the proposed rehabilitation project. With the creation of the Azhar Park on the west side of the walls, it is visualised that, "this old connection will be re-established and Aslam Square gradually equipped to serve both as pedestrian link and as a forum for commercial activity and social interaction ..." Siravo [2]. Improving the Square's built fabric thus includes the elimination of the informal vehicular parking, the upgrading of public utilities, paving and lighting. The improvement scheme is thought to be completed by a façade improvement programme for the residential and commercial buildings facing the square combined with a selective restoration task of the 14th Century Aslam Mosque.

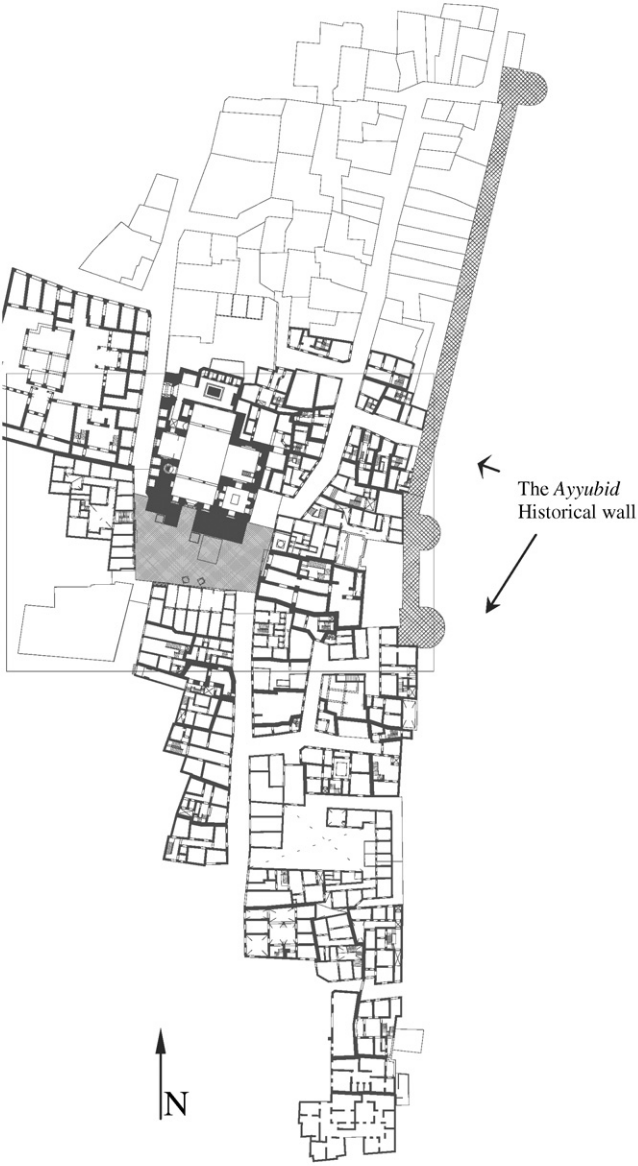


Fig. 1. Site plan of Aslam Square in the Darb el-Ahmar district, historic Cairo.

The historic alley of el-Drab el-Asfar (Fig. 3), on the other hand, is also undergoing a rehabilitation project that raises questions on the new *sparkling* look of the place [3–5]. Following the completion of the work, Williams [5], for instance, described the different attitude towards the project: "*Completed in* 1999*, enthusiasts applaud the sparkling new quality of work; purists bemoan the lost of patina of age*". The project was enlarged to include renovation of the infrastructure, pedestrianisation of the alley, introduction



Fig. 2. The stone facades of Aslam Mosque occupying the northern boundaries of the square.

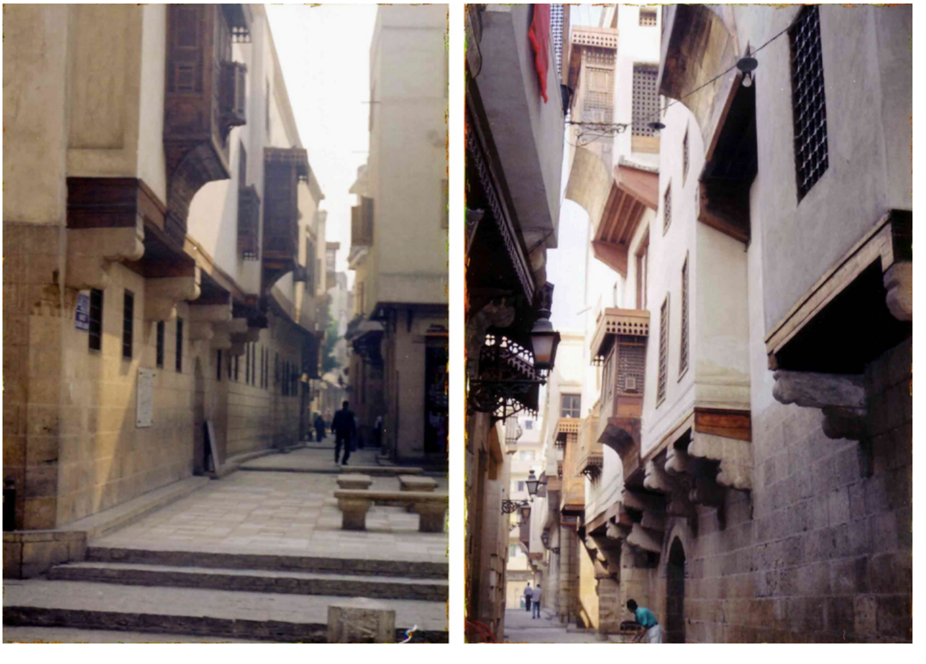


Fig. 3. The recently restored historic alleyway of el-Darb el-Asfar, historic Cairo.

of limestone pavement as well as re-painting and re-plastering of the alley's external facades [6].

It is argued that the two intervention projects have led to changes in daylight levels and reflections in the space and hence modify the visual perception of the place itself. This paper investigates the impact of the configuration of space as well as the selective materials on daylight performance and hence its potential role to preserve the original visual experience and the sense of identity of place. The paper investigates the complex relationship(s) between the daylight performance, the configuration of space and identity in the two selected cases of medieval quarters in Cairo.

2. Daylight performance and physical context

Daylight performance in an urban context depends on a combination of direct sunlight, diffused skylight and the reflector of light from the facades and the ground. Daylight literatures identified a number of technical variables that are related to the characteristics of space configuration that impact on the daylight performance.

2.1. The frame configuration variables

Reflected light of the other building facades is one of the well-recognised strategies that have been used to illuminate the building interiors and the areas around buildings [7,8]. Matus [9] suggested that façades surfaces, as source of reflected light, have a role in the enhancement of urban open spaces. Tregenza [10] also introduced a split-flux technique of determining the mean internal illuminance of space in a sunlit street with an opposing faç ade. Wa-Gichia [11] argued that the opposing facade of the buildings is a potential passive daylighting device to the internal sphere under clear sky conditions. He stated that the reflectance of the opposing facades and the geometry of the sectional profiles are among the main variables that affect daylight propagation and performance. Similarly, Tsangrassoulis et al. [12] investigated the potential of vertical south-orientated facades to reflect daylight onto the opposing facades under sunny conditions. Under clear sky conditions, three parameters determine the contribution of the reflective vertical plane to the total energy. These are the reflection specification of the plane, its orientation, and the horizontal distance separating this plane from the target point in the space.

2.2. The floorscape configuration variables

Ground plane is also considered a potential source of reflected light that could play an important role in increasing or decreasing the total amount of light reaching a station point in a room or space [7,8]. For daylighting of open spaces, the contribution of ground-reflected light to total energy is mainly influenced by *floorscape* (ground plane) surface area, the reflection specification of the floor materials and the height at which the daylight is calculated. The influence of the ground-reflected light is however diminished for spaces further away from the ground [11]. Effective ground reflection, on the other hand, is a function of predominant sky conditions. It has been stated that horizontal surfaces are more effective on overcast sky conditions, whilst vertical surfaces are more useful in clear sky conditions [8].

2.3. The space configuration variables

Studies concerned with the morphological definition of the space introduced a set of geometrical variables to evaluate the enclosure quality of the space. A number of morphological variables, such as the width to height or the height to $\frac{1}{2}$ length ratios, have an influence on the daylight propagation of the space. Dekay [13], for example, has recommended that the height and width relationships to be between 1:1 and 3:1 in the built urban environment if adequate daylight is to be obtained. Sky opening (sky view) factor, an urban quality factor, is also used in previous works as a measure of daylight availability in the urban fabric [14]. This ratio represents *the percentage of the sky visible from a point* [15,16].

3. The daylight simulation model of the historic case study

Previous studies showed that daylight performance is directly related to the predominant sky conditions, solar altitude, the sky cover, humidity and pollution ratio and the season type (the track of the sun). The impact of such technical and environmental variables on the daylight performance in the recently restored el-Drab el-Asfar alley, the indigenous characteristic urban pattern of old Cairo has been simulated. The output of the simulation exercise is used in the following sections to investigate the role of configuration on the performance of daylighting in the newly refurbished built heritage (Fig. 4).

A combination of *photogrammetric* and CAD software with lighting simulation tool are employed. The *photogrammetric* approach is used to define the geometry of the building in the lack of the required detailed architectural drawings of the historical buildings. Mantzouratos et al. [17] used a similar integrated approach. A 3D CAD model for the selected case study is created (Fig. 5). Appropriate photometric properties were assigned to the model and detailed hourly meteorological data for the cloud cover, diffused and direct solar energy (via using the meteo-file in TOWNSCOPE III software) and parameters for the relative humidity and atmosphere turbidity were selected. The simulation is primarily conducted to assess the solar access and sky opening characteristics of the developed model. Direct, diffused and reflected components of daylight via solar access analytic tool of a selective setting in the Cairene context are simulated for June and December.

A system of reference points is structured alongside the alleyway case study (Fig. 6). A set of 22 points was employed to examine the change in the daylight performance in the two simulated old and recently restored scenes. Similarly, a system of four axes, consisted of 39 points is used to examine the daylight performance in Aslam Square. The four axes are plotted within the square field of vision (Fig. 4). A height of 1.8 m has been selected to explore daylight performance at the eye level height. The sky-opening factor at each point was also calculated and the overall solar access is simulated.

4. Performance of daylighting in the two selected space configurations

The simulation modelling investigated the variability in daylight performance pre and after the intervention scheme in the alleyway site and a comparative analysis is made to measure the extent of the impact of façade improvement schemes in the two selected space



Fig. 4. Site plan illustrates the contour lines of the four adopted axes.

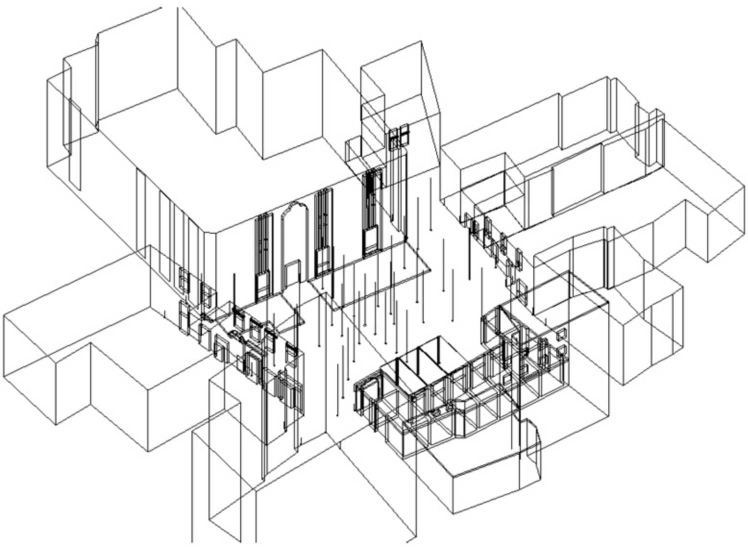


Fig. 5. Benchmark distribution system in the square/axonometric view.

configurations on the daylight performance in Cairo. The output of the comparative analysis of the two selected spaces (the square and the alleyway configurations) at different seasons is shown in Table 1.

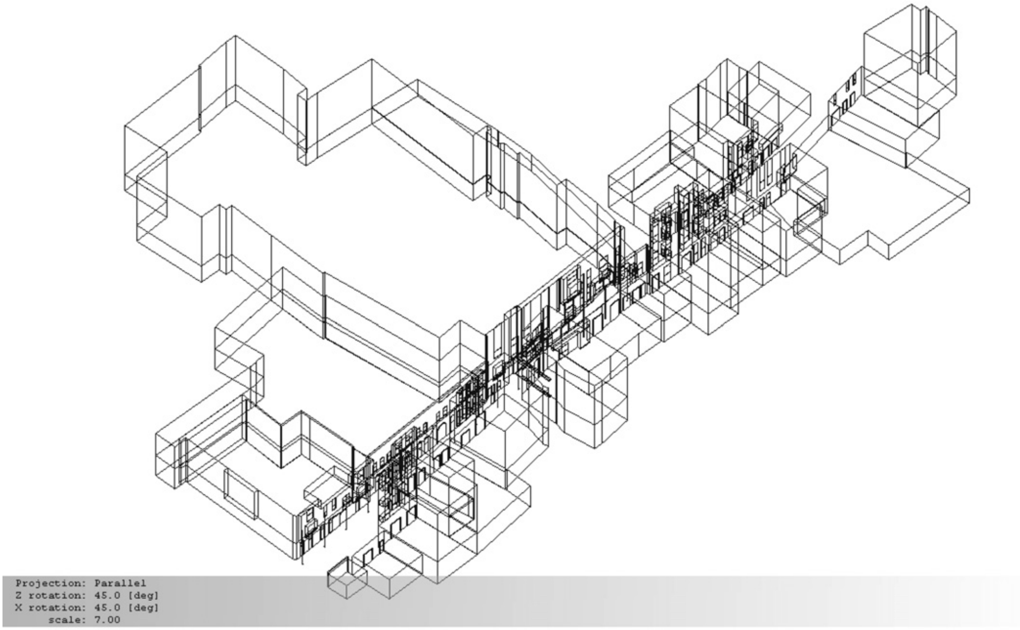


Fig. 6. Benchmark distribution system in the alleyway/axonometric view.

Table 1
The percentage of the increase in the reflected components of daylighting and total daylighting levels in both case studies

The case studies	Increase in reflected energy of daylight (%)	Increase in the total energy of daylight (%)	The total average of daylight energy in the square and the alley (wh/m^2)
Square: axis 1/June	31.07	0.89	5012.0
Square: axis 1/December	27.6	2.13	962.7
Square: axis 2/June	30.25	0.82	5240.9
Square: axis 2/December	25.98	2.48	943.7
Square: axis 3/June	31.77	1.01	5051.1
Square: axis 3/December	28.88	2.45	958.8
Square: axis 4/June	27.46	0.59	5143.2
Square: axis 4/December	22.86	1.62	953.1
Alleyway/June	35.48	1.31	4172.5
Alleyway/December	33.75	8.98	428.9

Table 1 shows that the square experiences an increase of as much as 30.14% in the reflected energy during summer time. The application of this scheme in the alleyway configuration, on the other hand, has also led to a slightly higher increase of 35.48% in the reflected energy at mid June the 15th (Fig. 7).

The results show that the impact of the reflected component and its contribution to the total daylight level is much higher in the alleyway configuration than in the square. Table 1

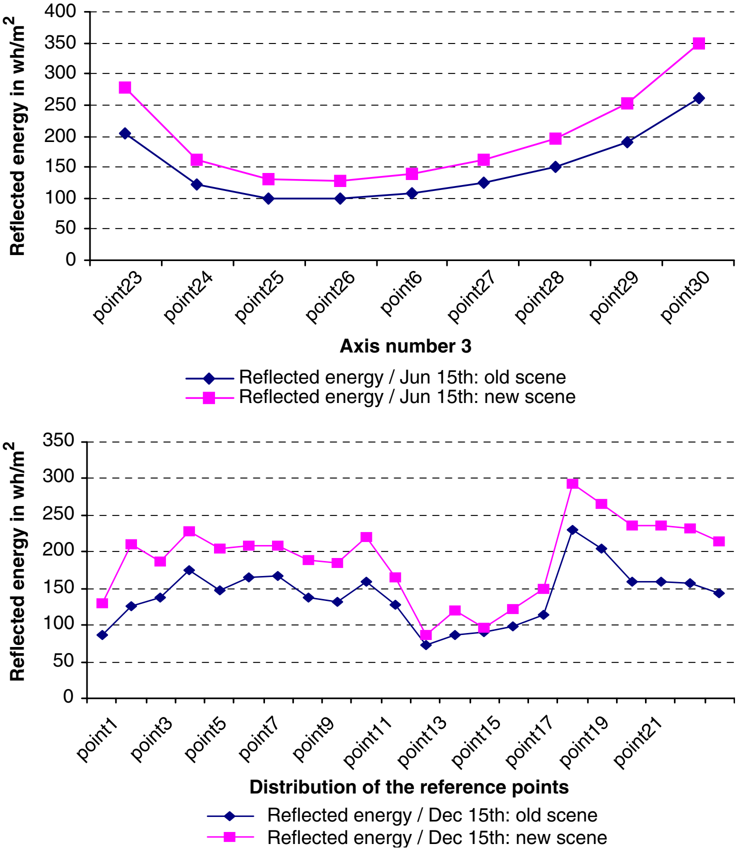


Fig. 7. The increase in the reflected component after the refurbishment of both the square and the alleyway in mid June.

shows that while there would be an average increase of 0.83% in the total daylight level due to rehabilitation in the square, there was 1.31% increase in daylight level in the recently refurbished alleyway. In such dense urban form, a slight increase can lead to a noticeable change of ambience and in the visual identity of the alley. The difference in the reflected component is more noticeable in wintertime with as much as 8.98% in the alleyway space (Fig. 8) and an average of 2.17% in the square site (Fig. 9). The increase in energy of the reflected component during wintertime is a merit that contributes to improving the visual comfort for the alley's residents. In hot summer climatic conditions of Cairo, a slight increase in the reflected component adds value and compensates for the lack of acceptable daylighting level in the heavily shaded alleyways.

An increase in the reflected component, on the other hand, leads to a change in the visual experience of the place. A heritage place with an increase in daylighting levels will appear more 'sparkly'. For professionals and tourists, the place can then appear to lose its characteristics. This conflict between the interests of local residents and those for the tourist industry surfaces in this situation.

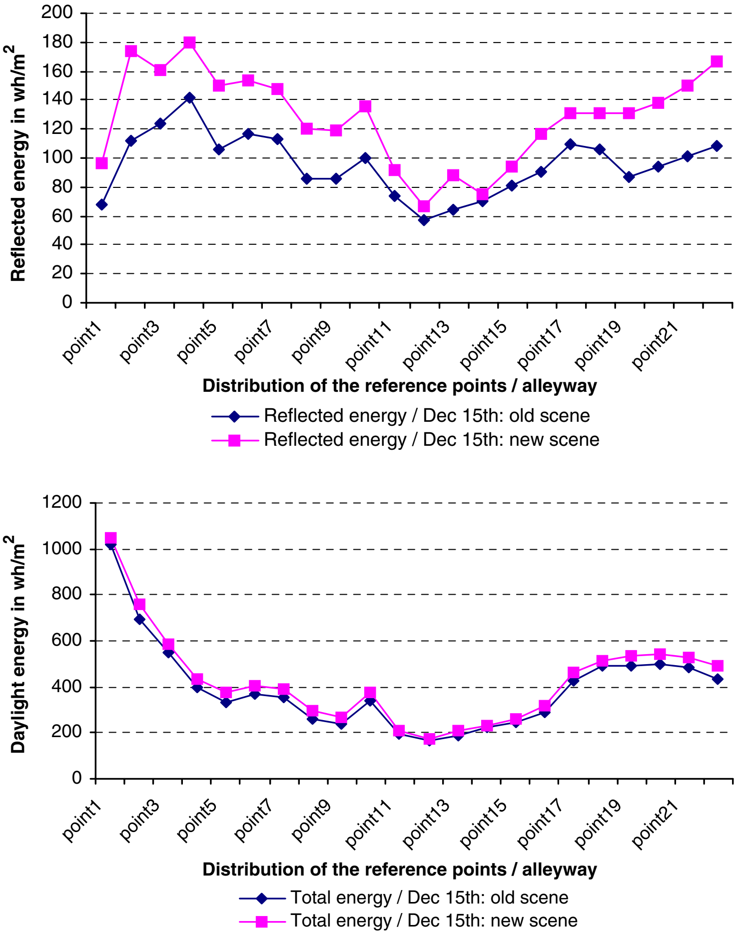


Fig. 8. The variability in the reflected and total daylight levels due to the rehabilitation in the alley in mid December.

The output of the simulation of axis 4 (running north-south) is of particular interest as the mosque occupies the northern end of the square. In both winter and summer times, the analysis of daylight levels across axis 4 shows a less significant increase (Table 1) in comparison to the three other axes. This is a result of the restoration of the mosque. The low reflectivity of the stone materials maintains an equilibrium of daylighting levels in the square in each season regardless of the intervention projects.

Analysis of the reflected and total energy of daylight in the square shows that in a low-compact configuration environment, intervention and restoration of building materials have little impact on daylighting levels. The results also show the sensitivity of the narrow configuration of the alleyway to an intervention scheme has and would largely influence daylight performance. While the square configuration shows a flexibility towards a range of intervention actions, in terms of daylighting performance, the compact characteristics of the alley proved to be much more sensitive to similar actions.

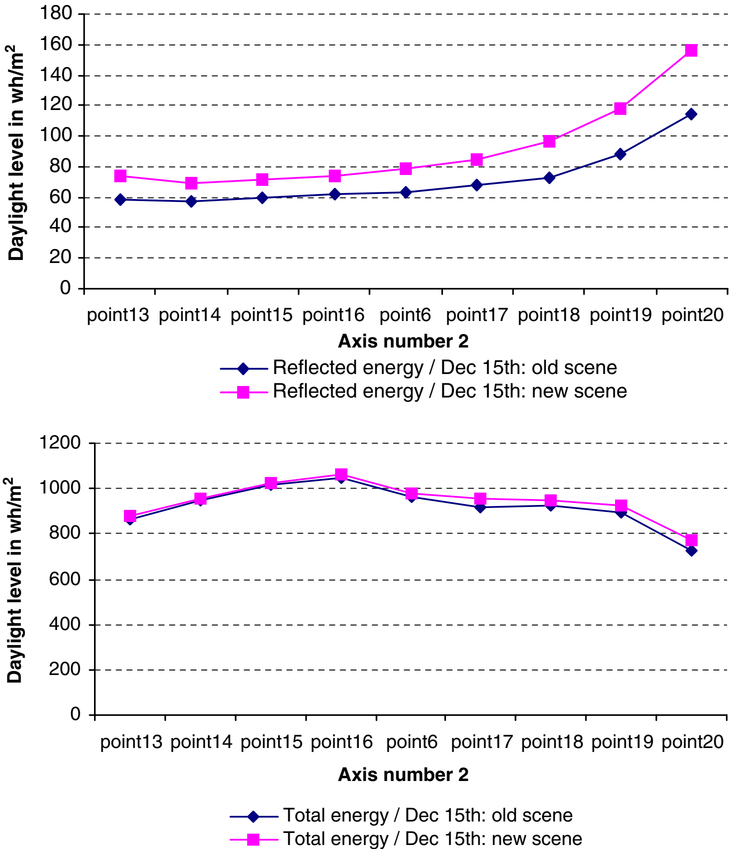


Fig. 9. The variability in the reflected and total daylight level due to the rehabilitation in the square in mid December.

5. Daylight performance and the space configuration relationship

The performance of the daylighting in relation to the sky-opening factor is also examined within the two selective urban configurations. The output of the correlation analysis of the direct, the diffused, the reflected and the total daylighting performance with the sky opening factor in the square and alley configurations at two different times of the year is illustrated in Tables 2 and 3.

The tables show that in the two selective urban components and in both seasons, a linear relationship occurs between the performance of the diffused component and the sky-opening factor. The results obtained under clear sky conditions confirm those obtained in previous research under overcast sky (e.g. [18]). In both cases sky-opening factor are strongly related to the levels of the diffused component of daylighting.

The relation between sky-opening factors and the levels of the direct components of daylighting under clear sky conditions is also examined. At the four selected axes in the square, an acceptable correlation is obtained between the direct component performance and the sky-opening factor in mid June. The strong correlation is a result of the high solar

Table 2
Correlation analysis of the daylighting performance (wh/m^2 day) with the sky-opening factor (%) in the square configuration

	The square case							
	Axis number 1		Axis number 2		Axis number 3		Axis number 4	
	15th June	15th December	15th June	15th December	15th June	15th December	15th June	15th December
Sky opening and direct component	0.7102	0.1977	0.697	0.1399	0.9556	0.2401	0.8292	0.4470
Sky opening and diffused component	0.9879	0.9878	0.9769	0.1399	0.9965	0.9964	0.9897	0.9896
Sky opening and reflected component	0.6881	0.6579	0.1365	0.1355	0.4286	0.8611	0.4102	0.9313
Sky opening and total component	0.7755	0.384	0.7478	0.5156	0.9587	0.8231	0.8880	0.029

Table 3
Correlation analysis of the daylighting performance (wh/m^2 day) with the sky-opening factor (%) in the alleyway configuration

	The alleyway case	
	15th June	15th December
Sky opening and direct component	0.177	Over shadowing
Sky opening and diffused component	0.9604	0.9603
Sky opening and reflected component	0.3144	0.3946
Sky opening and total component	0.2709	0.9558

altitude in summer in Cairo. The high solar altitude in summer led to the domination of the direct energy component in the overall total daylighting level. A linear relation of the total daylight level with the sky-opening factor was therefore obtained. In winter, the solar altitude and the obstruction of the sunlight in the square has resulted in a poor correlation between the total daylight level and the sky-opening factor. The only exception was for axis 3, where the gained strong correlation is due to the impact of the projecting features of the configuration (shading devices). The exclusion of the shaded points (22,31) from the analysis of this axis also showed in weak relationship ($R^2 = 0.0839$) between the total daylight level and the sky-opening factor in mid winter, similar to the other three axes.

In the case of the alley, contradictory relations have been obtained between the total daylighting performance and the sky-opening factor. A strong correlation is obtained in wintertime as a result of the predominance of the diffused component and the obstruction of the low sunlight (low solar altitude), whilst a poor correlation is gained in summer time as direct sunlight is still obstructed.

The relationship between the reflected component and space configuration is more complex than those of the previous two components. Strong relations are only observed in spaces wide enough to allow reflection of direct energy from the surrounding surfaces. This usually occurs during wintertime when sunlight is low enough to reflect from the

surrounding surfaces rather than direct impact on the ground. This has been observed in Cairo's square scenario. The alleyway close configuration did not allow for a large amount of reflected energy. There was therefore a poor relationship between the reflected components and sky-opening factor.

6. Conclusion

Old Cairo, with its unique medieval value of Islamic heritage, is going through major conservation and restoration projects. These projects have created a healthy public debate on the extent of the success in preserving the identity of the Cairene context. The rehabilitation schemes for el-Darb el-Asfar historic alley and Aslam Square present two paradigms on the potential role of daylighting as an ingredient in preserving the place identity. A combination of *photogrammetric* and 3D digital technique has been utilised in building up a digital model. The dynamic performance of daylight's three components within the cases under study has been examined using a lighting simulation tool. The performance of the reflected component is traced by simulating the impact of the original and recently used materials based on two separate simulation exercises of each case under study. A comparative analysis is conducted to assess the impact of implementing the façade improvement scheme to the selective space configurations on the daylight performance. The correlation between the daylight performance and the space configuration relationship is also examined to provide a more general insight to predict the daylight performance in the selective built fabric under the climatic conditions of Cairo.

The results show that the implementation of the refurbishment scenarios in the alley has led to an increase in the gained reflected energy more than its counterpart in the square case. This is related to the compactness of the space configuration that raises different influences on the performance of the daylight's reflected component. Due to the high-compact configuration of the alley, the gained increase in the reflected component could (would) exert more impact on the sense of the ambience of the narrow alley than on the square site.

The results also indicate the potential benefits of using light coloured materials to improve the environmental ambience for the alleyway's residents and the square's users and compensate for the lack of an acceptable daylight level during wintertime. Unfortunately, such improvements might contradict the authenticity of the place as a heritage site. Whilst it is not the aim of this paper to discuss the values in either argument, it is important to note that the sustainability of the place should be owned by the users rather than preserving what they would consider a nuisance.

The linear relation between the sky opening factor and the diffused energy component was previously utilised to predict the daylight propagation within an urban sitting under overcast sky conditions. The currently gained similar relationship within the urban fabric under Cairo's clear sky conditions indicates another strategic approach that could be utilised in order to control the daylight performance under different sky conditions. In hot summer climatic conditions of Cairo, the low sky-opening ratio characteristics of the urban setting would contribute to the desirable reduction of the high-gained daylight levels and would ensure a more comfortable daylight level.

Whilst the performance of the diffused and the total daylight levels shows a close relationship with the space configuration characteristics, the performance of the reflected component proved to be more complex as a function of multi-variables.

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